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Calculating Geological Reserves of Horizontal Wells by Using Water Drive Characteristic Curve Analysis Method

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Abstract: *Water drive characteristic curve analysis method is a method of using oil production prediction of recoverable reserves and reserves, is mainly the analysis of the relationship between cumulative oil production, cumulative water production and cumulative liquid production, in oilfield development has been widely used. This paper analyzed the method used in the calculation of the geological reserves of horizontal well water flooding characteristic curve, taking Daqing oilfield Nan1- Ping25 horizontal wells as an example, analysied the geological reserves of the horizontal well was applied to calculate the water drive characteristic curve, analyzed the results of horizontal well geological reserves, provided favorable information for evaluating the development effect of horizontal wells.*

Keywords: *Horizontal well, Geological reserves, Water flooding characteristic curve, Single well*

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I. Introduction

With the development of oilfield entering extra high water content stage, horizontal well becomes an important means of tapping remaining oil in thick oil reservoir. However, there is no mature method for calculating the geological reserves of horizontal wells. The geological reserves of horizontal well can not only provide technical and evaluation basis for the feasibility of horizontal well spreading, but also provide geological basis for further improving oil recovery. Reasonably and scientifically calculating the geological reserves of horizontal wells becomes an important problem in the development of horizontal wells.

Overview of water flooding characteristic curve analysis method

Water drive characteristic curve analysis method has been widely used in the development of domestic and offshore water flooding oilfield. Waterflooding characteristic curve is suitable for water flooding oilfield(block or single well), When the water content reaches a certain level, the injection production system is basically balanced and the water drive is stable, it can be used to calculate the water drive control reserves, recoverable reserves and recovery, and predict the future development of the oil field. It is characterized by direct production and regression calculation by means of production data. The method is simple and practical, and the result is reliable[1]. At present, there are 3 kinds of commonly used water drive characteristic curves[2 ~ 4].

1.1 Type A waterflooding characteristic curve

Type A waterflooding characteristic curve is one of the widely adopted methods in our country. It describes the semi logarithmic linear relationship between cumulative water production and cumulative oil production in water drive development oilfield. When the comprehensive water cut rises in a certain stage, the relation between cumulative oil production and water production is:

$$\log W_P = a_1 + b_1 \bullet N_P \qquad (1)$$

In the formula: W_P is cumulative water yield, 10^4t;
N_P is cumulative oil production, 10^4t;
a_1 is the intercept of the type A water drive characteristic curve; b_1 is the slope of the characteristic curve of the type A water drive.

1.2 Type B waterflooding characteristic curve

Type B waterflooding characteristic curve method is the semi-logarithmic linear relationship between water oil ratio and cumulative oil production. Main relations:

$$\log WOR = a_2 + b_2 \bullet N_P \qquad (2)$$

In the formula: WOR is water - oil ratio;

N_P is cumulative oil production, 104t;
a2 is the intercept of the type B water drive characteristic curve;
b2 is the slope of the characteristic curve of the type B water drive.

1.3 Type C waterflooding characteristic curve

Type C water flooding curve is a linear relationship between ratio of accumulated liquid production to cumulative oil production (accumulated oil ratio) and cumulative liquid production in waterflooding oilfield. The law was presented in 1982 by the C.H.HasapoB in the form of empirical formulas. Main relations:

$$L_P / N_P = a_3 + b_3 \bullet L_P \qquad (3)$$

In the formula: L_P is cumulative fluid volume, 10^4t;
N_P is cumulative oil production, 10^4t;
a_3 is the intercept of the type C water drive characteristic curve;
b_3 is the slope of the characteristic curve of the type C water drive.

II. The Example Analysis

The A, B of the same oilfield is parallel to the two water drive characteristic curves, type B water drive characteristic curve can be obtained by moving on type A waterflooding characteristic curve. In this paper, the type A and C water flooding curves had been made with the production data of Nan1-2-Ping 25 wells in the south of No. 1 South district.

1.4 Type A waterflooding characteristic curve

The type A water drive characteristic curve of Nan1-2-Ping 25 wells in the south of No. 1 South district is shown in the following figure:

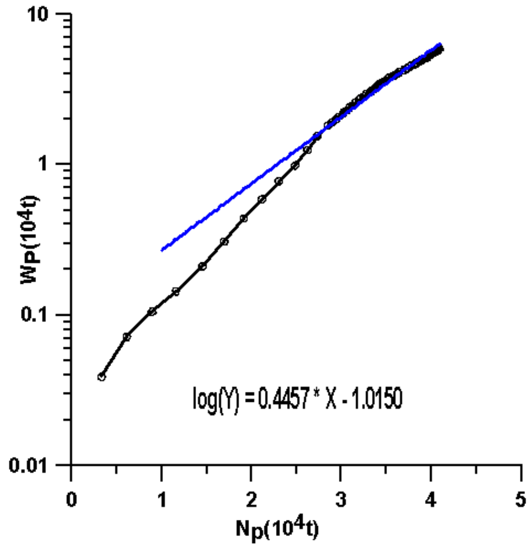

Figure 1 Type A waterflooding characteristic curve of Nan1-2-Ping 25 wells in the south of No. 1 South district

The characteristic curves of type A waterflooding were obtained by regression. The related parameters were: $a_1 = -1.015$, $b_1 = 0.446$, correlation coefficient r = 0.988.

When the final moisture content of the oilfield was 98%, the recoverable reserves could be calculated according to the following formula:

$$N_R = \frac{\log(WOR)_{\max} - (a_1 + \log 2.303 b_1)}{b_1} \qquad (4)$$

In the formula: N_R is recoverable reserves;
WOR is water oil ratio;
a_1 is the intercept of the type A water drive characteristic curve;
b_1 is the slope of the characteristic curve of the type A water drive.

In the formula $(WOR)_{Max}$ is the maximum water-oil ratio, when the final moisture content of the oil field is 98%, the corresponding maximum water-oil ratio $(WOR)_{Max} = 49$.

The formula above is simplified as:

$$N_R = \frac{1.6902 - (a_1 + \log 2.303 b_1)}{b_1} \qquad (5)$$

By substituting a_1=-1.015, b_1 = 0.446 into the above formula, N_R = 6.044 * 10^4t.
According to the statistical research methods provide the reciprocal of Tong Xianzhang, 135 domestic and foreign water flooding reservoir geological reserves and the corresponding type A curve of straight line were painted in double logarithmic paper. Linear regression was used to obtain the following empirical formula:

$$N = 7.5422 b_1^{-0.969} \qquad (6)$$

In the formula: N is the geological reserve of water flooding oilfield, 10^4t;
b_1 is the slope of the characteristic curve of the type A water drive.
Substituted b_1 = 0.446 into the formula and got N = 16.503 x 10^4t.
The relevant empirical formula of the recovery rate of water flooding oilfield is:

$$E_R = 0.1326(1.3279 - a_1 - \log b_1) b_1^{-0.031} \qquad (7)$$

Put a_1 = -1.015, b_1 = 0.445 into the above formula, and got: E_R = 36.63%.

2.2 C 型水驱特征曲线

The type C water drive characteristic curve of Nan1-2-Ping 25 wells in the south of No. 1 South district is shown in the following figure:

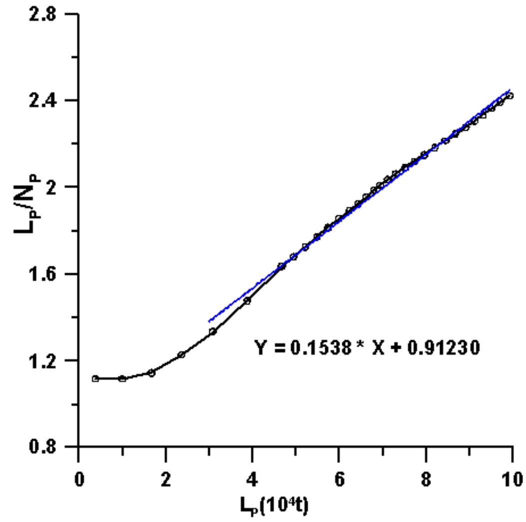

Figure 2 Type C waterflooding characteristic curve of Nan1-2-Ping 25 wells in the south of No. 1 South district

After curve fitting, the regression line was derived, b_3=0.154, a_3 = 0.923, correlation coefficient R = 0.996. It showed that the theoretical foundation of the formula was reliable and the coefficient of linear correlation was high. The parameters a_3 and b_3 were taken into the lower form to calculate the recoverable reserves:

$$N_R = \frac{1 - \sqrt{a_3(1 - f_{wl})}}{b_3} \qquad (8)$$

In the formula: N_R is recoverable reserves, 10^4t;
f_{WL} is the economic limit moisture content, taking 98%;
a3 is the intercept of the curve;
b3 is the slope of the curve.
By calculation, the recoverable reserves of this horizontal well N_R = 5.611 * 10^4t.
According to the relevant literature[5], in the Nazarov empirical formula, the reciprocal of the line slope is the movable oil reserve of the oil field:

$$N_{om} = 1/b_3 \qquad (9)$$

In the formula: N_{om} is an available reserve of oil field;
b3 is the slope of the curve.
The so-called oil field movable oil reserves, that is, the reserves that can fiow in the reservoir, according to the above slope b_3=0.154. According to the slope b_3=0.154 above, the movable oil reserves are calculated to be 6.493 * 10^4t.

The recoverable reserves of horizontal wells calculated by type A and type C waterflooding characteristic curves were 6.044 * 10^4t and 5.611 * 10^4t respectively. It could be seen that the results of the two water drive characteristic curves were basically similar. To date, the cumulative oil production of horizontal wells was 4 * 10^4t, combined with the horizontal well development effect, it showed that type A and C waterflooding characteristic curve analysis method had good effect in the application of this horizontal well.

III. Conclusion

(1) When there is accurate production data of single well, the water drive characteristic curve analysis method can be adopted to predict the single well geological reserves and recoverable reserves of the water drive horizontal well;

(2) The geological reserves of horizontal wells calculated by water flooding characteristic curve method were 16.503 * 10^4t, so far, the cumulative oil production of this well was 4 * 10^4t, indicating that the horizontal well had great potential for exploitation.

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